

# Advanced Vehicle and Power Initiative

A Government, Industry and Academia White Paper

led by the U.S. Army's and the Research, Development & Engineering Command's

Tank-Automotive Research, Development & Engineering Center, (TARDEC)

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## Executive Summary

The Advanced Vehicle and Power Initiative (AVPI) supports National Energy Policies and Army Energy Strategy. The AVPI is a 20 year non-tactical vehicle (NTV) and renewable power initiative geared to accelerate Army adoption of advanced propulsion vehicles and increase use of renewable energy to reduce petroleum consumption and emissions, and which are capable of importing and exporting grid electric power or islanded power to installations (Army bases.) Qualifying advanced propulsion vehicles for this initiative are battery electric vehicles (BEV), hybrid electric vehicles (HEV), hybrid hydraulic vehicles (HHV), plug-in hybrid electric vehicles (PHEV) and fuel cell electric vehicles (FCEV). The AVPI integrates use of renewable energy at installations for vehicle charging and incremental grid electrical supply. Qualifying renewable energy technologies for this initiative are solar, wind, geothermal, biomass waste-to-energy, co-generation, and electric and hydrogen energy storage. The AVPI is a \$4.6B investment program (average of \$229M per year) designed to:

- reduce NTV petroleum and green-house-gas (GHG) emissions by 60% - minimum of 2% per year
- secure Installation grid electrical supply
- provide a tested, proven game-plan and the tools for the balance of the nation to do the same – Energy Security for the Nation

Figure 1 below pictorially shows the relationship of vehicles, renewable energy systems, the electrical grid, and installations and the modes of operation to achieve the AVPI benefits.

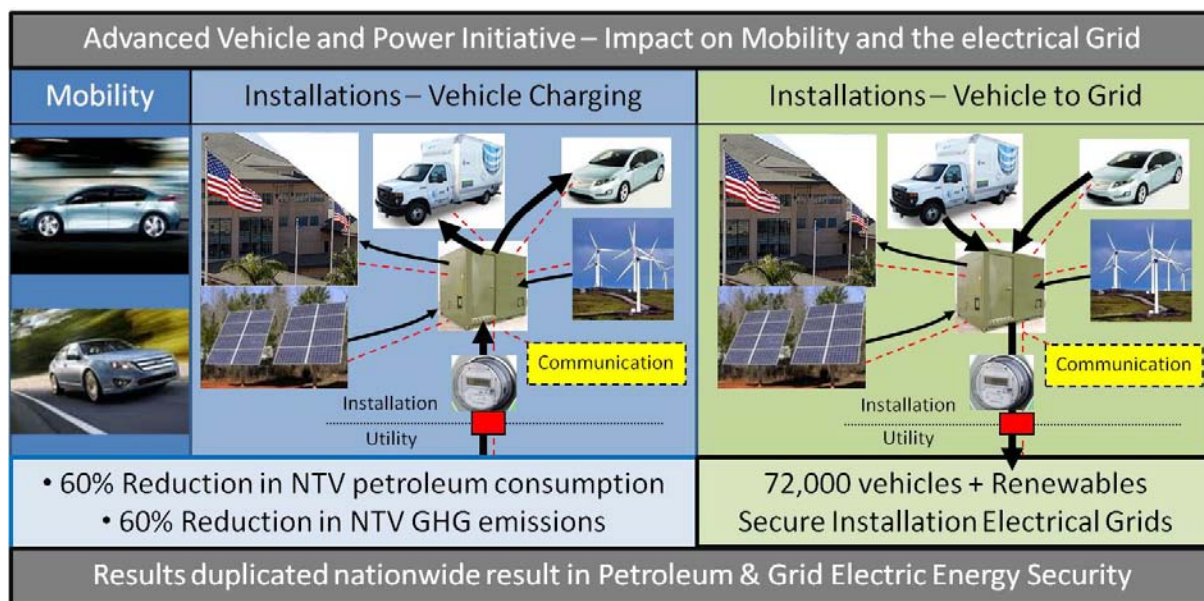


Figure 1 - Advanced Vehicle and Power Initiative Goals

The AVPI accelerates purchase adoption of advanced vehicles nationally and accelerates creation of approximately 80,000 energy efficient, sustainable jobs in the first ten years of the plan. The AVPI executed within the Army shortens a 10-year 30% truck market adoption (~63,000 jobs creation) of advanced vehicles by approximately 2 years and executed DOD or Government-wide reduces this time by 3 and 4 years respectively. The automotive and renewable energy markets will see significant job growth as well.

Supporting the National Energy Policy requires that the Army's NTV fleet reduce petroleum consumption by two percent per year through 2020 relative to a 2005 baseline and to use low GHG emitting vehicles.<sup>1</sup>

- The AVPI seeks to support the Army's Energy Security Implementation Strategy<sup>2</sup> policy by promoting adoption of commercialized advanced propulsion vehicles and by planned introduction of the next generation of advanced propulsion vehicles into the Army's NTV fleet at military bases in the continental United States (CONUS).
- Advanced propulsion vehicles are defined in this document as vehicles with onboard electrical storage that have the potential to integrate with the electric infrastructure via Vehicle-to-Grid (V2G) capable systems.
- Vehicles in stationary mode (parked) can supply electricity to: a) electric tools, b) local buildings, c) micro-grids, d) the larger electric grid, and e) other vehicles. Army fleets and bases with sizeable fleets and electric grid infrastructure are prime locations for demonstrating the linkage between vehicles and the grid.
- The AVPI supports this goal and others in the strategy by outlining a path to guide the long-term military installation vehicle investment. The plan is designed to exploit a plugged-in advanced NTV fleet capable of providing back-up power for an installation micro-grid for improved robustness of installations' energy supply.

The AVPI employs a two phased approach.

**Phase I** of the initiative recommends incremental funding (~\$125 million per year for ten years) for all Army CONUS Base replacement of the conventional NTV fleet over time with HEV, BEV, and other commercialized advanced propulsion vehicles capable of meeting immediate and near term mandated reductions in petroleum use. The specification for individual fleets and resultant benefit of implementation of the advanced vehicle fleet over time will be developed and monitored with an operational systems model that will predict and provide comparison measurement to intended achievement of goals.

**Phase II** is designed to accomplish two major steps – pilot integration and implementation. Phase II/Step 1 is a development process and focuses on evolving the next generation of advanced vehicle technologies including PHEVs and FCEVs into export power capable electrical grid-tied generation systems. After further development of the systems model, decisions targeting the most appropriate technologies to be employed will be determined. **The AVPI program would then place a significant number of these advanced vehicles at selected military installations in CONUS.** Within Phase II/Step 1, the mission will be not only to integrate PHEV and FCEV's into installations and reduce petroleum consumption and GHG emissions but to help define and validate the standard for facility and vehicle requirements for bi-directional connection to the electrical grid – i.e. Grid-to-Vehicle (G2V) and V2G – including micro-grid/smart grid control of these vehicles to support islanding of installations. Phase II/Step 1 also seeks to utilize renewable energy supply for vehicle energy storage system charging and maximize the NTV fleet's net reduction of GHG generation. The cost of Phase II/Step 1 is approximately \$72 million which includes advanced vehicle incremental costs, renewable energy systems, modeling of

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<sup>1</sup> EISA 07 - Energy Independence and Security Act of 2007, Executive Order 13514 and Executive Order 13423

<sup>2</sup> Army Energy Security Implementation Strategy – January 2009

vehicles and installations, system integration, grid management developmental efforts, and facility modifications.

Phase II/Step 2 will capitalize on the lessons learned from Step 1 **by refining the models and defining the vehicle incremental investment path** (~\$150 million per year for fifteen years) to dramatically reduce petroleum consumption and emissions, and provide substantial electric power generation to the installation through V2G capable PHEVs and FCEVs purchased in volume. An additional \$1 billion (67 million/year for 15 years) in renewable energy systems would provide for fleet vehicle energy system recharging needs and offset the current installation electrical grid consumption.

Phase II/Step 1 will install a renewable energy supply of nearly 1 mega-watt (MW) or over 7000 mega-watt-hours (MWh) per year. The initial investment will be distributed to three to five installations executing a grid integration plan without affecting power quality.

Phase II/Step 2 will install an additional 180 MW (one million MWh per year when complete) of renewable power generation systems into the balance of Army installations – more than 10% of the Army's yearly electrical power purchase.

Through these investments the program will assess, employ and validate the technical advancements that are needed to overcome the inherent challenges associated with the broad introduction of plugged-in advanced vehicles and their capacity to connect to the grid. The AVPI will validate the large-scale viability of transferring infrastructure and transportation energy resourcing away from petroleum exclusivity and creating instead an interconnected portfolio of conventional, alternative and renewable energy supply systems.

In total, the AVPI would provide \$4.6 billion in funding to offset the cost premium of adopting advanced vehicles and renewable energy systems vs. conventional petroleum-based energy supply systems. The initiative will leverage previous Department of Defense (DOD) and Department of Energy (DOE) investments aimed at creating a domestic manufacturing and technology infrastructure for the development and supply of American advanced vehicles, key components, and renewable energy. It will also benefit from technologies emerging from upcoming large-scale private fleet demonstrations.

Additional benefits of the AVPI include: :

- Sustainable job creation of the advanced vehicle and renewable technology industries
- Taking a lead role for the nation in vehicle to grid electrical system integration and standards development and implementation
- Stimulating the production of advanced plug-in vehicles to help drive down production and product costs to facilitate broader consumer adoption
- Establishing installation grid connectivity between vehicles and renewable sources

## Objective

Historically, the Army operated with the assumption that low cost energy would be readily available when and where it was needed. Today, however, reliable access to affordable, stable energy supplies is a significant and increasing challenge for the Army, particularly in deployed operations. The Army is committed to ensuring a more secure energy position by increasing efficiencies and lowering corporate demand for energy.

The Army recognizes productive synergies between the commercial and defense sectors, and advocates industry partnerships that develop technologies which optimally manage sources, loads and energy storage and allow islanding from and selling power back to the commercial grid from Army installations. By working with domestic energy technology leaders, Army installations could serve as a proving ground to accelerate the development of smart grid technologies which enable vehicle-to-grid connectivity.

The objective of the AVPI is to accelerate Army adoption of advanced vehicles that reduce petroleum consumption, reduce emissions, and generate electrical power. The AVPI supports Army energy security goals and helps to implement the Net Zero Energy installations discussed in more detail in the Motivations section below. Army leadership lowers adoption risks and costs for broad adoption by the nation's vehicle fleet and electrical grid as well as for future integration into the DoD tactical vehicle fleet and forward operating bases (FOB).

## Assessing the Challenge

The Army has the largest fleet within the DOD and is a microcosm of the Government and the Nation. The DOD has just less than 200,000<sup>3</sup> NTVs that could potentially be electrified, and approximately 40 percent of these belong to the Army. Table 1 below shows the Fleet breakdown for the Government, DOD, Army, and Army CONUS Bases. The table also shows the relative penetration of advanced vehicles (generally 1% or less of the fleet) and current status of the petroleum reduction relative to the 2005 baseline (government mandate for 2%/year.) Note that for 2009 the reduction in petroleum consumption goal is 8% in order to meet the 2%/year objective of the mandate. Also note that CONUS Bases fell short of petroleum reduction goal by 15% (8% goal + 7% increased consumption) in 2009. A large percentage of the Army's fleet (85%) is leased and as such the Army routinely turns over a significant portion of its inventory and is therefore a good candidate for the AVPI strategy for advanced vehicle introduction. Generally, an automobile lease is 3 to 4 years and the light truck leases are 7 years or 100,000 miles.

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<sup>3</sup> GSA, Federal Fleet Report, FY 2009



Organization	Total Vehicles	Auto	Trucks	Other	% of Fleet with Advanced Propulsion	EISA 2007 Petroleum Reduction Mandate by 2009	Actual 2009 Petroleum Reduction vs. 2005	Relative Percentage Short of Goal
Government	651,000	240,000	402,000	9500	<1% <sup>2</sup>	8%	-1.7%	9.7%
DOD	195,000	86,000	102,000	6600	<1%	8%	9%	1% margin
Army	83,000	44,000	36,000	2900	~1%	8%	2%	6%
CONUS Army Bases	72,000	38,000	32,000	2444	~1%	8%	-7%	15%

**Table 1 - Government, DOD, Army, and Army CONUS Fleet Inventory**

Army installations, the DOD, and the Government are acting to reduce petroleum consumption. Operational changes being encouraged are consolidation of trips, video conferencing, using mass transit, improving routing, and avoiding idling. Clearly much progress can be made by cultural change. However, an increase in Army operational tempo (the activity level required in order to accomplish the Army's assigned mission(s)) has increased petroleum consumption. More significantly the Army fleet has increased 17% from 2005 to 2009 to support the growth in Army operational tempo. Therefore, a strategy designed around adoption of motive transportation that consumes less petroleum is required to ensure successful reduction in petroleum consumption to compensate for variability of operational tempo. Current vehicle-based change strategy includes:

- use of smaller/more fuel efficient conventional vehicles
- adoption of all-electric neighborhood (low speed) electric vehicles (4000 vehicles to be adopted by the Army over a 5-year period – starting 2010)
- retiring older and less fuel efficient vehicles
- purchase or lease of hybrid and electric vehicles as funding allows - introduction of 1500 leased HEV sedans is planned for 2010 with support of a General Services Administration (GSA) led/funded initiative.

The bottom line is that for predictable, reliable reductions of petroleum use, a plan for massive conversion of the Army vehicle fleet is required (approximately 8% the fleet per year - 6600 vehicles/year). Current Army installation funding does not cover the incremental funds required to enable broad adoption of advanced vehicles. Installations are motivated and ready to adopt advanced vehicles if funds are made available enabling the change. Expanding the initiative government-wide would increase the advanced vehicle incremental investment volume to 50,000 vehicle replacements per year to meet the 2% per year goal for petroleum reduction.

## Motivations

Shaping the AVPI are ten motivating factors that include:

- Addressing energy security and national security needs
- Petroleum reduction – Efficiency and Conservation
- Reduction of CO<sub>2</sub> and other GHG Emissions
- Validation and utilization of previous private and government manufacturing infrastructure investment
- Establishing a grid connection game plan for advanced vehicles to maximize petroleum and GHG emissions reduction
- Experimentation and fact finding with “Net Zero Energy” Installation Implementation – “Net Zero Energy” is the concept of the installation generating as much energy as it uses throughout the year
- Validation of advanced propulsion vehicles across weight classes
- Strengthening the connection between military, other government agencies, and technology developers
- Improving capabilities for the warfighter
- Homeland Security
- Career Long Job Creation

### ***Energy Security and National Security***

In FY08, the Army’s total energy consumption was over 180 trillion BTUs costing more than \$4B. This consumption included the purchase of approximately 880 million gallons of fuel and 9.1 million MWh of electricity. Facilities are the major energy consumer for the Army in both peacetime and contingency operations. Facilities and NTVs account for 72% of total Army energy consumption during peacetime operations, and 39% for contingency operations.<sup>4</sup> Reliable, robust supply of energy is a key factor in ensuring continued Army operations and capabilities. Reference to Federal Laws and National and Army Policy aimed at relieving dependence on petroleum and the fragile grid are included in the Addendum. In summary, the Army’s energy security goals are:<sup>5</sup>

**Supply** - Reduced energy consumption ensures adequate supply.

**Survivability** - Increased energy efficiency across platforms and facilities improves survivability.

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<sup>4</sup> Defense Science Board. More Fight – Less Fuel (Feb 08)

<sup>5</sup> Army Energy Security Implementation Strategy

**Surety** - Increased use of renewable/alternative energy improves grid robustness.

**Sufficiency** - Assured access to sufficient energy supplies.

**Sustainable** - Minimize the consumption of resources and reduce the impact on the surrounding communities and environment.

## ***Petroleum Reduction – Efficiency and Conservation***

Today, petroleum fuels 96% of the nation's total transportation needs. To meet this need, petroleum and refined fuels are increasingly imported from overseas and from regions of the world which are unstable or outright unfriendly to the interests of the United States. The nation now imports more than 60% of its petroleum, up from 40% just thirty years ago.<sup>6</sup> As much as two-thirds of this imported oil comes from the Middle East and OPEC nations, the purchase of which essentially transfers billions of dollars of wealth out of the country. Therefore, reducing or displacing petroleum use is of paramount national security interest.

Key to reducing petroleum demand is through efficiency and conservation improvement. This can be achieved through the implementation of a variety of energy efficient platforms including advanced propulsion vehicles such as electric, hybrid-electric, fuel cell electric, hybrid hydraulic and plug-in hybrid electric vehicles. These technologies use energy more efficiently, utilize stored energy to optimize vehicle operation, and capture vehicle kinetic energy during braking (regenerative energy).

## ***Reduction of CO<sub>2</sub> Emissions***

The combustion of fossil fuels such as coal, petroleum and natural gas accounts for most of the world's manmade GHG emissions, primarily carbon dioxide (CO<sub>2</sub>).<sup>7</sup> According to the Environmental Protection Agency (EPA), about 83% of energy consumed in the United States in 2006 came from fossil fuels.<sup>8</sup> The EPA also states that the transportation sector accounted for about 28% of the total US GHG emissions produced in 2006. Within the transportation sector, passenger cars and light duty trucks (which include all vehicles commonly used for personal transportation) produced 62% of GHG emissions. Recent research suggests that plug-in vehicles could substantially reduce carbon dioxide emissions through reductions in fossil fuel consumption by passenger vehicles. The greatest reductions in carbon dioxide emissions depend on generating electricity used to power the vehicles from lower-emission sources of energy.<sup>6</sup>

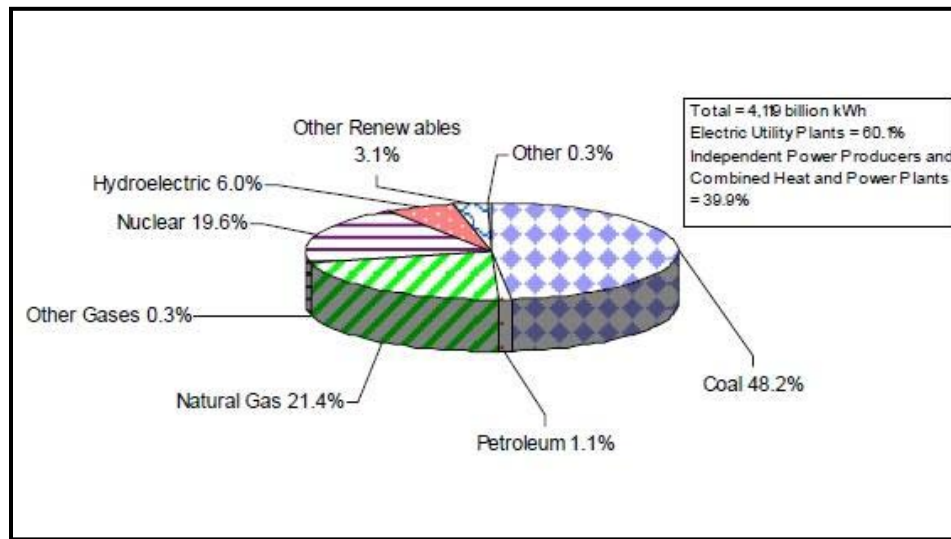
PHEVs and FCEVs are an excellent platform for meeting the goals of the AVPI for petroleum and subsequent GHG reduction. For example, **a PHEV that has a 40 mile all-electric range and a 50 mile typical daily usage can provide an over 80% reduction in petroleum consumption versus a comparable internal combustion engine (ICE) vehicle.** In addition, the advanced propulsion architecture can reduce GHG generation by over 80% as well - providing that non-fossil fuel generated electrical energy is used for energy system charging. Currently, over 70% of the nation's electric grid energy supply is generated from fossil fuels with nearly 50% of the power generation coming from coal as indicated in Figure 2. Utilizing the current composite mix of power generation for PHEV energy system charging would impede the potential GHG reduction improvement of greater than 80% and yield just 40%.

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<sup>6</sup> US Energy Information Agency

<sup>7</sup> GAO report

<sup>8</sup> Energy Information Administration – Annual Energy Review 2008



**Figure 2 - US Electric Energy Generation<sup>9</sup>**

Coal, while being a very affordable energy source for the electric grid, contributes heavily to GHG generation. Table 2 below provides the relative emissions level of the typical fossil fuel options used for energy generation. A GHG generation reduction of 60% is possible by reducing coal's contribution to the energy generation pie from 48% to just 20% and increasing renewable and nuclear energy source contribution to make up the difference.

Fossil Fuel Emission Levels Pounds per Billion Btu of Energy Input			
Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0	0.007	0.016

Source: EIA - Natural Gas Issues and Trends 1998

**Table 2 - Fossil Fuel Green House Gas Emissions Comparison**

<sup>9</sup> U.S. Energy Information Administration, Form EIA-923, "Power Plant Operations Report"

## ***Validation and Utilization of Existing Manufacturing Infrastructure Investment***

The Nation recently invested more than \$2.4 billion in its advanced vehicle manufacturing infrastructure through American Recovery and Reinvestment Act (ARRA) grants. This investment will help significantly increase the manufacturing capacity for advanced vehicles and thereby drive down the end unit cost to the consumer. A majority of the ARRA investment (\$1.5 billion) focused on establishing domestic manufacturing capability of large-format, automotive batteries instrumental for BEV, PHEV, and FCEV vehicle systems. The investments' target is to drive battery costs down from the current cost of about \$1000/kilowatt-hour level to less than \$500/kilowatt-hr. However, there is still a significant need for more funding to investigate durability, useful life and manufacturing tolerance requirements in large volumes. This is a critical element since the potential cost of a battery pack replacement during vehicle warranty periods for technology released "too early" (i.e. prior to cost reducing advancements) could bankrupt vehicle and battery manufacturers, and critically damage or potentially destroy the perceived long-term viability of this technology.

## ***Advanced Vehicle Grid Integration and GHG Reduction Opportunity***

The United States Government Accountability Office (GAO) published a report in June 2009 regarding Federal Energy and Fleet Management. Their primary finding was that plug-in vehicles offer potential benefits, but high costs and limited information could hinder integration into the federal fleet.<sup>10</sup> Several of their findings include:

*"For plug-ins to realize their full potential, electricity would need to be generated from lower emission fuels such as nuclear and renewable energy rather than the fossil fuels – coals and natural gas – used most often to generate electricity today."*

*"...factors may emerge over the longer term if the use of plug-ins increases, including managing the impact on the electrical grid and increasing consumer access to public charging infrastructure needed to charge vehicles."*

*"...agencies must meet a number of requirements covering energy use and vehicle acquisition – such as acquiring alternative fuel vehicles and reducing facility energy and petroleum consumption – but these sometimes conflict with one another. For example, plugging vehicles into federal facilities could reduce petroleum consumption but increase facility energy use."*

The AVPI directly addresses the concerns and chief findings laid out in the GAO report. The AVPI offers an avenue in which to explore solutions to overcome these concerns in a relatively low-risk manner in a real-world environment. The Phase II/Step 1 scope is a five-year development that:

- Uses renewable energy for vehicle charging thus reducing the grid's high GHG emissions
- Uses renewable energy to address increased electrical energy needs of a plugged-in fleet
- Develops a standard of V2G protocol and validates using plugged-in vehicles to stabilize the grid

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<sup>10</sup> GAO-09-493 report page 1

- Substantially reduces the risk of full scale nation-wide implementation

Fundamentally, the AVPI facilitates a plugged-in fleet becoming an asset to an installation's grid vs. a liability. Phase II/Step 2 covers the incremental costs of plug-in vehicles and eliminates another key hurdle hindering fleet adoption.

### ***Experimentation with “Net Zero Energy” Installation Implementation***

The concept of Net Zero Energy is for installations to produce as much energy as they consume on an annual basis. Net Zero Energy action combines greater end-use efficiency with onsite power generation from renewable sources and distributed generation. Energy efficiency improvements within facilities include:

- Use of programmable thermostats
- Replacing conventional lighting with LED, florescent and compact florescent lighting (CFL)
- Turning off all computer equipment (including monitors and printers), ventilation fans, pumps, radios, battery chargers, power supplies/ transformers, exhaust fans, coffee pots, any appliance or equipment that is running when no one is using it and turning them off every night.
- Installing 24/7 motion sensor controls on all interior lighting.

Achieving Net Zero Energy is both a tactical and non-tactical goal for the Army. The AVPI will reduce the risk associated with tactical deployments by implementing Net Zero Energy systems at CONUS installations first. The AVPI will contribute to the Army's stated goal of 5 Net Zero Energy installations by 2015 and 25 installations by 2025 through Phase II investments in renewable energy.

As installations transition to Net Zero Energy positions with the capability to island their own independent energy generation, advanced vehicles can play a critical role. In an islanded situation, energy storage is required to stabilize the power system. The electrical storage capacity represented by advanced vehicles can provide this function in an emergency or contingency situation. Advanced vehicles capable of supplying power to the grid can also serve as mobile generation assets. Defining the role of advanced vehicles in a net zero or electrically islanded installation will require close coordination between partnered agencies. Existing work at partnered agencies includes programs focused on developing models of net zero and islanded installations. These models provide insight into the role advanced vehicles can play in these situations and help assess where the vehicles have the greatest impact.

### ***Validation of Advanced Propulsion Vehicles Across Weight Classes***

Much of the current federal policy and independent studies relating to advanced propulsion has focused on the light-duty vehicle segment. This is logical because cars and light trucks consume about two thirds of the transportation sector energy. **Medium and heavy trucks make up 4% of all vehicles nationwide, and consume 20% of the nation's vehicle fuel.** Medium and heavy duty trucks are very important to the Army because they are critical tactical assets and constitute about a quarter of its GSA fleet. Most importantly, the medium/heavy duty truck sector offers the greatest dual-use connection to the tactical fleet. The scale of the AVPI generates volumes in the medium/heavy duty sectors critical to pre-commercial advances in technology and infrastructure that will eventually translate to tactical trucks.

## ***Strengthen the Connection Between Military and Technology Developers***

The AVPI complements ongoing commercial and military projects that tap into industry expertise to develop and deploy advanced technologies into military fleets. The use of advanced modeling and simulations techniques will give both the Army and Industry an opportunity to understand the interrelated effects that these complex technology implementations will cause and help industry refine their offerings for commercial and military use. The volume execution proposed by the AVPI will increase production volumes, help reduce product cost and subsequently stimulate greater commercial and military adoption of advanced vehicles. The AVPI will also encourage continued advancement and commercialization of technology that the Army needs. The AVPI scope ensures productive long-term military-industry relationships and increases the military's stature as a test-bed for advanced technologies.

## ***Improve capabilities for the warfighter***

Increased mobile power and reduced petroleum consumption also meet the needs of the warfighter. The Mine Resistant Ambush Protected (MRAP) vehicles are a good example of the need for mobile power. Many MRAP vehicles have been outfitted with a 570 amp/24 volt alternator as well as a separate, engine-driven 570 amp/24 volt alternator to provide enough power for detection and communication systems. Used together, these systems provide roughly 15 kW of continuous mobile power capability. Migration of advanced vehicle systems into tactical vehicles will likely provide 30 kW or more of continuous mobile power. Grid export power will enable forward operating base (FOB) stationary electrical power supply when needed. Advanced vehicles will reduce petroleum consumption and improve vehicle range. Reduced operational fuel consumption in theater will expose the warfighter to fewer improvised explosive devices (IEDs) as well as reduce unintended combative interaction with the enemy. An executed AVPI will advance capability within US industry to support future tactical vehicle and combat vehicle development. Installations and local communities CONUS, Outside Continental United States (OCONUS), and at FOBs will benefit from the AVPI. Advanced vehicles with export power will improve the capabilities of the warfighter due to enhanced operational capabilities, vehicle range and potential modes of silent watch and mobility.

## ***Homeland Security***

The AVPI Phase II executed at Army Installations provides the nation with a fleet of vehicles capable of export power which could support relief efforts after natural disasters outside of the installation's borders. The advanced vehicle fleet can be used to aid in recovery and supply electrical power for communities that have suffered an event that destroys grid electric infrastructure. Advanced vehicles if adopted by the Department of Homeland Security would be capable of supporting mobile and stationary power demands for electrical loads associated with border protection and detection systems.

## ***Career Long Job Creation***

Driving adoption of advanced vehicles will help create jobs in the short and long term. The AVPI is especially helpful to truck industry adoption of advanced vehicles. The Army's Hybrid Truck Users Forums (HTUF) analysis<sup>11</sup> which is based on user (fleet owners) feedback indicates that the hybrid truck market penetration could reach 30% for the vocational truck market and approximately 4% of the heavy duty truck market by 2020 as is shown in Figure 3. This level of market adoption was examined by the

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<sup>11</sup> Job and Economic Benefits from Hybrid Trucks – Thousands of High-Tech Jobs Today – Tens of Thousands by 2020 – CALSTART

Union of Concerned Scientists and CALSTART and could help create as many as 63,000 jobs by 2020.<sup>12</sup> The analysis does assume market incentives to stimulate truck ownership. However, the scope of the AVPI exceeds these market stimulations assumptions. The AVPI executed increases expected purchase rate of truck adoption by approximately 80% and reduces the time to 30% market penetration by approximately 2 years. An AVPI-like DOD or Government wide adoption would increase expected early year production volumes by 200% and 700% respectively, resulting in a 3 and 4 year reduction in the time to 30% market penetration and the 63,000 jobs.<sup>13</sup> The volume of the AVPI will help create sustainable high technology job growth and strengthen the US transportation industry.

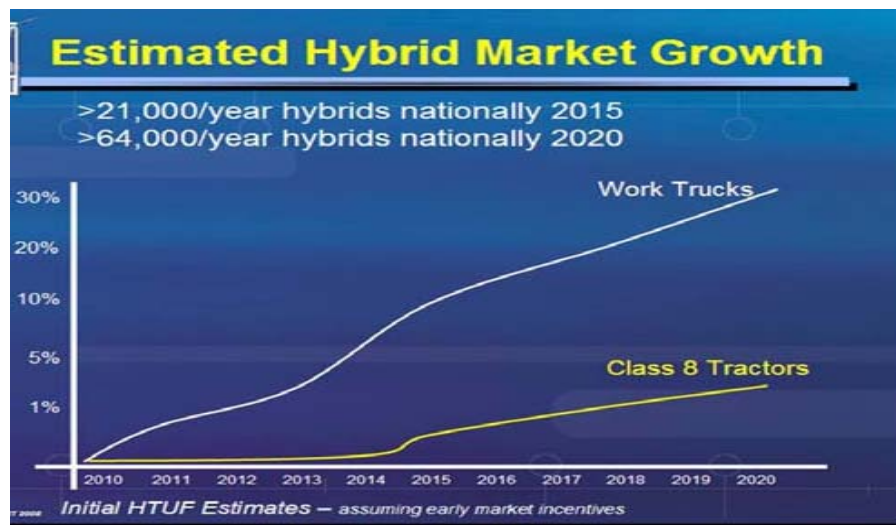


Figure 3 - Estimated Hybrid Truck Market Growth

## Proposed Approach - Advanced Propulsion Fleet

The AVPI is a two-phase, 20 year initiative designed to reduce Army non-tactical fleet petroleum consumption and GHG emissions generation by at least 60% and to secure Army installations' electrical grid power supply. Phase I and Phase II are to be completed concurrently. Phase I is a 10 year acquisition execution plan of commercialized advanced vehicles. Phase II spans 20 years – Phase II/Step 1 is a 5 year effort that includes 3 years of capital investment and 2 additional years of implementation and Phase II Step 2 is a 15 year acquisition execution plan of export power capable advanced vehicles and renewable charging infrastructure.

<sup>12</sup> Delivering Jobs – The Economic Costs and Benefits of Improving the Fuel Economy of Heavy-Duty Vehicles – May 2010, Union of Concerned Scientists and CALSTART

<sup>13</sup> Derived from original research and manipulation of the data from references 11 and 12



## ***Phase I – HEV and BEV Procurement***

Phase I models and executes an acquisition plan to convert the Army's fleet with currently available and commercialized vehicles such as HEV and BEVs. Phase I provides for a fully modeled plan and for the incremental buy-down funds to the installations for vehicle purchase/leasing. The GSA vehicle schedule options currently include HEV and BEV options for approximately 40% of the categories. Figure 4 provides a visual representation of many of the HEV and BEV options available on the 2010 GSA Schedule.



**Figure 4 - GSA 2010 Schedule Options of HEVs and BEVs**

Not only are the vehicles available on the GSA, the broad commercial automotive market adoption (>5000 units sold/month) of HEVs that began in 2004 is shown in Figure 5. The market has shown consistent growth until 2008 when the economy slowed. Interestingly, the drop in sales of hybrids was 14% vs. the conventional vehicle market drop of 21% in the same period despite the higher incremental cost of HEVs.

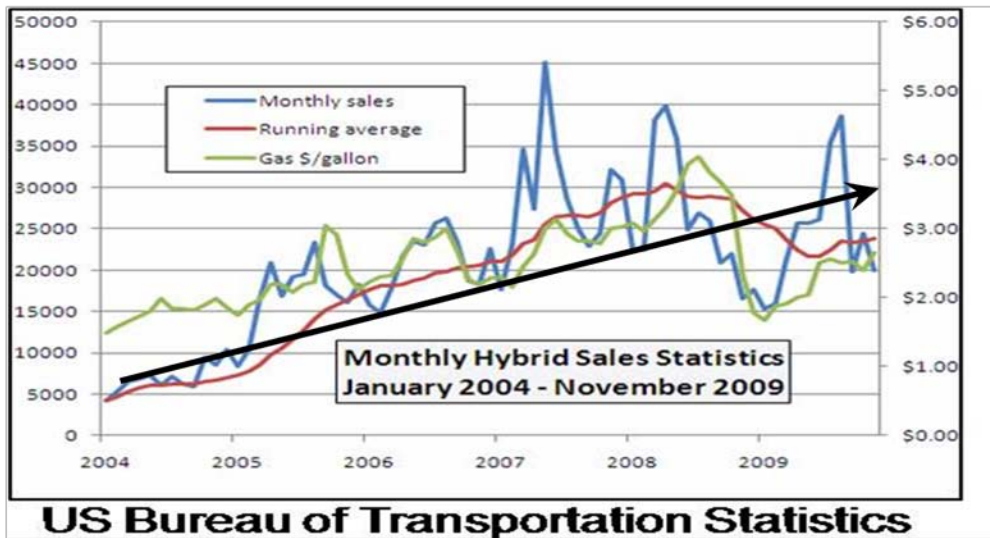


Figure 5 - Automotive HEV Sales Per Month

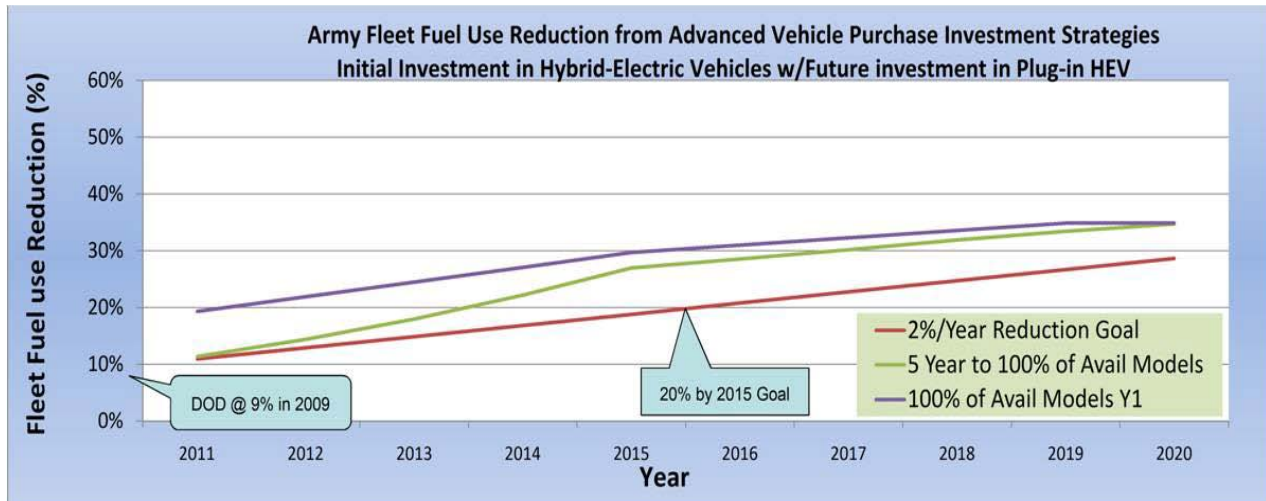
As a part of the planning for the initiative, three options for adoption of HEVs and BEVs were modeled.

- The most modest replacement option investigated was to replace the minimum number of vehicles to meet the 2%/year mandate – roughly 8% of the fleet per year.
- The most aggressive option investigated was to cull the fleet year-one and replace all vehicles with their available HEV/BEV option from the GSA schedule.
- An intermediate approach was to cull and replace available vehicles over a five year period.

The three approaches had different results and the resultant fuel economy improvement is shown in Figure 6 below. The cost of each approach was calculated as well.

- The 2%/year cost required approximately \$125M/year funding for 10 years and produced an acceptable result – nearly 30% reduction in petroleum use by 2020.
- The 100% year-one approach was much more costly (\$1500M year one and by 2020 was more than double the cost of the 2%/year option) and did not result in a significantly better result in petroleum reduction ~35%.

As a result of this analysis, it was concluded that a 2%/year improvement plan (an average 8%/year adoption rate for a total 80% fleet replacement by year 10) was most effective vs. the cost to implement and net value.



**Figure 6 - Army Non-tactical Fleet Replacement with Advanced Vehicles vs. Reduction in Petroleum Consumption**

Table 3 below shows the breakdown of the Army's non-tactical fleet by type as well as by ownership – owned outright, leased from the GSA, and commercial leases. An 8% per year replacement rate applied evenly yields the bottom line Phase 1 total of roughly 6600 vehicles replaced with advanced vehicles per year. The Army typically replaces 8000 to 14,000 vehicles per year. The Army's owned vehicle fleet age is double that of the leased fleet. Therefore, the opportunity exists for executing vehicle replacements without breaking leases or replacing owned vehicles prematurely. An AVPI-like Government-wide initiative would involve 54,000 vehicle replacements per year at an incremental replacement cost of \$1.1B per year to meet the 2% per year petroleum reduction.

Army Non-Tactical Vehicle Fleet	Light Duty Vehicles					Medium Duty Vehicles					Heavy Duty Vehicles	Total Vehicles
	Sedans & Station Wagons	Vans	SUVs	Light Trucks		Buses	Amb	Vans	SUVs	Trucks		
				4x2	4x4							
OWNED	386	551	1,106	961	2,545	119	58	240	380	2,357	2,238	10,941
GSA Lease Fleet	19,393	12,093	5,386	5,570	4,376	2,195	265	7,536	430	9,530	3,574	70,348
Non-GSA Lease	100	336	36	153	244	262	6	249	72	38	75	1,571
Total Fleet	19,879	12,980	6,528	6,684	7,165	2,576	329	8,025	882	11,925	5,887	82,860
Phase 1 - Yearly Replacement	1590	1038	522	535	573	206	26	642	71	954	471	6629

**Table 3 - Army Non-Tactical Fleet & Phase 1 Yearly Vehicle Replacements with HEV and EV's**

### ***Phase II/Step 1 -PHEV and FCEV Pilot Integration***

Phase II/Step 1 of the AVPI is a 5-year integration of a large-scale advanced propulsion fleet at three to five military installations in CONUS. The most effective plan for deployment of vehicles and energy generation infrastructure will be developed using modeling for decision making based on cost benefit and performance criteria while providing a basis for measurement of effectiveness. This effort will focus

on vehicles that are grid-tied and can provide exportable power. Key stakeholders will work closely during the program to achieve all of the objectives of this Initiative. The program as envisioned provides a rolling introduction of fleets comprised of approximately 250 light duty and 80 medium to heavy duty advanced propulsion vehicles, replacing a significant portion of each installation's current conventional NTV fleet with PHEV and FCEV vehicles.

## Site Selection Criteria

The three to five Army installations selected must be evaluated to find those which provide the potential for an optimized mix of renewable resources; namely, those which will remain strategic assets and those which have experience with advanced propulsion vehicles. A rigorous site selection plan will be implemented which includes Army Senior Energy Council suggestions about the best sites for solar, geothermal, wind potential, waste-to-energy (biomass), and BRAC findings. **The support of local, state or regional partnerships, either through direct funding or in-kind support, will be a key discriminating factor in selecting sites.** Other possible selection criteria could be: EPA air pollution non-attainment and near non-attainment zones, geographical importance, support from utility companies, fleet composition, existing renewable energy infrastructure, and degree of dependence on the grid.

## Phase II/Step 1 - Plug-in Fleet Timing & Distribution

Table 4 below depicts a notional concept of the PHEV and FCEV fleet size for the grid integration development. Light duty vehicles include a range of sedans, sport utility vehicles and passenger pick-up trucks. Medium and heavy duty vehicles include Class 3 - 8 (10,001 lb - >33,000 lb gross vehicle weight (GVW)) trucks, buses, and a variety of vocational vehicles. Consideration should also be given to non-road vehicles and equipment, e.g. loaders, excavators and bulldozers that are commonly used on military installations and as such are potentially available for pilot implementation.

Vehicle Integrations, # of vehicles		Y1	Y2	Y3	Y4	Total
Featured Base A	Light Duty	Plan and ramp up program	18	28	38	84
	MD/HD		7	9	11	27
Featured Base B	Light Duty		18	28	38	84
	MD/HD		7	9	11	27
Featured Base C	Light Duty		18	28	38	84
	MD/HD		7	9	11	27
Consolidated	Light Duty		54	84	114	252
	MD/HD		21	27	33	81
				Total Vehicles		333

Table 4 - PHEV and FCEV introduction at 3 Military Installations - Number of vehicles introduced per year.

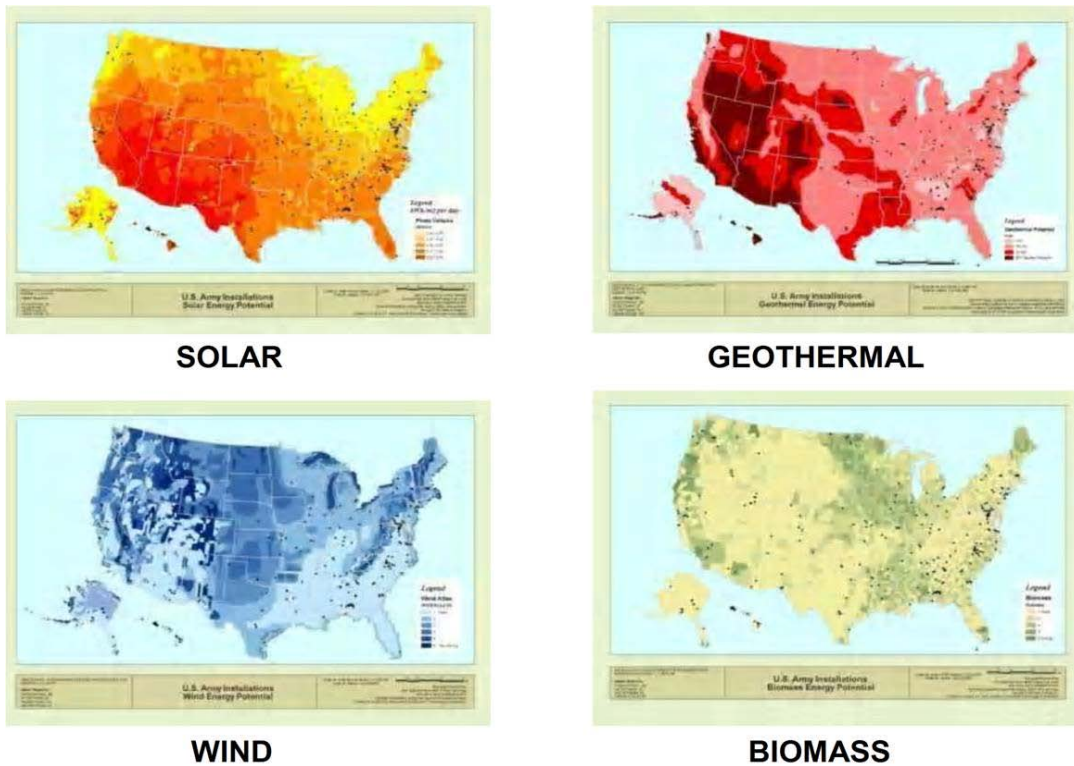
Assuming that the average light duty vehicle's export power generation capability to the grid is 15 kW and the MD/HD truck and bus is 30 kW the fleet power generation maximum capability is approximately 6 MW.

## **Vehicle Infrastructure**

Phase II/Step 1 includes a phased introduction of vehicle charging and V2G infrastructure including energy consumption measuring tools like advanced utility power meters; hydrogen refueling stations; vehicle fast chargers; and plug-in vehicle charging “banks” with both 110 and 220-volt connectors. Bi-directional AC Level 1 and 2 charging systems (up-to 20kW of AC supply to the vehicle) will likely be integrated into the vehicle by the OEMs. However, larger charging systems are likely to be integrated into installations. The larger systems Electric Vehicle Supply Equipment (EVSE) are an emerging industry and are approximately sized as: AC Level 3/3 phase AC (up to 50kW), and DC Level 1 (up to 20 kW), Level 2 (up to 80kW), and Level 3 (up to 200kW). The cost, size, weight, life, and power capability of these systems are better suited for stationary applications. Non-mobile solutions for high-power “fast” charging maximize the value of the asset (multiple-vehicle use capable) and reduce the cost and timeline for commercialization. The AVPI Phase II/Step 1 includes the cost of integration and utilization of these larger systems. The standards being developed (Smart Energy Alliance, SAE, ISO, NIST, IEEE, and others) to manage the interactions between the utilities, EVSEs, and vehicles are under development for unidirectional as well as bi-directional grid and vehicle power management and control. The AVPI will provide an environment to expedite proven application of these emerging standards.

## **Renewable Resources and Energy Generation**

Phase II/Step 1 includes the introduction of renewable energy generation at each of the three to five military installations. Generation activities will include the procurement of renewable energy infrastructure, the connection to the energy grid, the incorporation of distributed generation at the facility, and the management and maintenance of the energy supply assets. Optimized management of the system will allow for increased security (including the ability to “island” the base from the grid) and lowered energy costs including selling power back to the grid. Renewable energy generation will include the generation of energy from several different types of renewable resources. Four key national sources of renewable energy potential are graphically shown below in Figure 7. Clearly opportunities vary by region and the renewable energy mix for each installation will need to be tailored based on the most effective source of supply. Modeling and Simulation of each facility will be completed to determine the appropriate mix of vehicle and renewable infrastructure technology.



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**Figure 7 - National renewable energy source potential by geographic location**

Solar – Large-scale solar power using photovoltaic cells has great potential for installation applications. As an intermittent power source, solar power requires a backup supply, which can be partially attained with wind power. Local backup can be done with rechargeable batteries. This initiative will leverage lessons learned from Fort Irwin’s solar plant deployment. Fort Irwin in the Mojave Desert is where the Army has contracted to construct a 500-megawatt solar energy complex, which may expand to 1,000 megawatts in the future. Fort Irwin only needs 35 to 40 megawatts to operate, so the extra power generated will be sent to the closest electrical grid.

Geothermal – Geothermal power is cost effective, reliable, and environmentally friendly, but has previously been geographically limited to areas near tectonic plate boundaries. Recent technological advances have dramatically expanded the range and size of viable resources, especially for direct applications. This initiative will leverage lessons learned from Hawthorne Army Depot’s geothermal plant deployment. The 30 megawatt geothermal power plant will meet all of Hawthorne’s electrical power requirements on a 24/7 basis, independent of the commercial power grid, with essentially no greenhouse gas emissions.<sup>15</sup>

Wind – Wind power offers considerable potential for installation applications. Wind energy as a power source is attractive as an alternative to fossil fuels, because it is plentiful, widely distributed, and produces no GHG emissions. Electricity generated from wind power can be

<sup>14</sup> Renewable Resources – National Renewable Energy Lab

<sup>15</sup> Army information paper – SAIE-EP May 2010



highly variable. Because instantaneous electrical generation and consumption must remain in balance to maintain grid stability, this variability can present substantial challenges to the integration of large amounts of wind power into a grid system. As the levels of wind penetration increase, a grid energy storage capacity will be required to regulate the variability of the wind energy. Investigated will be the value in translating the incremental “excess power” available for stored electrical energy or stored hydrogen fuel and stationary fuel cells.

**Biomass or Waste-to-energy** – Biomass is matter usually thought of as garbage. Refuse contains biomass that can be reused. Recycling biomass for fuel and other uses cuts down on the need for “landfills” to hold garbage and can be used to produce electricity. Biomass includes dead trees, tree branches, yard clippings, left-over crops, wood chips and bark and sawdust. It can even include used tires and livestock manure, food waste, paper products that can't be recycled into other paper products and other household waste normally sent to the landfills. The end product can either be electrical power or chemical products, to include fuel or fuel blend stocks. This initiative will explore utilizing these waste resources and partnering with local communities to use their waste as well.

**Energy Storage** – This initiative will incorporate significant amounts of highly variable power generation onto a local grid that must be capable of being islanded for significant periods of time. The integration of variable energy generation will likely necessitate the introduction of large-scale energy storage into the local grid. Depending on the specifics of the generating mix and the available resources at the site, a wide range of technologies may be considered that includes batteries, fly wheels, compressed air, pumped hydro and chemical (e.g. hydrogen). All of the available alternatives will be assessed in terms of performance, cost and environmental impact.

Each installation requires a unique set of alternative energy solutions tailored to maximize the use of available energy resources. Developing the appropriate portfolio of alternative energy solutions at an installation determines the cost effectiveness of the power generation. The renewable and alternative energy sources at each installation will be selected to take advantage of the naturally available energy resources. Other alternative sources, such as waste to energy, can be used to support advanced vehicles at installations with few energy resources or to supplement variable wind and solar sources.

The renewable power systems for Phase II/Step 1 are notionally sized to charge the vehicle batteries in an 8 hour period. The remaining energy production capability of the renewable sources will be used to offset facility demands from the grid and contribute to the Army Net Zero Energy goals. A composite installed cost of renewable power was used to estimate cost of implementation. The approximate installed cost by energy source for power is shown in Table 5.<sup>16</sup>

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<sup>16</sup> Solar Data – California Energy Commission & Sharp, Akeena Solar, Solar Buzz

Wind Data – US DOE Annual Report on US Wind Power Installation, Cost, and Performance Trends: 2007... uses approx average cost & assumes 33% utilization

Waste to Energy Data - USEPA (2005), Landfill Gas... uses approximate average cost

Geothermal Data – Geothermal Power Generation a primer on low-temperature, small-scale applications 2000

<b>Renewable Energy Installed Cost</b>	<b>\$/kW</b>
Solar =	\$9,000
Wind =	\$3,300
Waste to Energy =	\$2,000
Geo Thermal =	\$2,200
<b>Composite =</b>	<b>\$4,125</b>

**Table 5 - Approximate Installed Cost of Renewable Power**

The use of renewable power for battery charging ensures that the:

- Incremental energy used for charging the vehicle batteries does not include fossil fuel and thus maximizes the net GHG reduction of the installed fleet.
- The incremental added supply ensures that the installation's electrical grid will not be stressed by the addition of vehicle charging demands.

In time of need, the PHEV and FCEV fleet and renewable energy sources can be used together for grid power. The net vehicle based power generation capability is 6MW for Phase II/Step 1.

At many installations, the power distribution system is privatized, which requires coordination with the system operator to successfully install the alternative energy system. To facilitate the required coordination and speed the installation process, the program will draw on the experience of partner agencies to field the required large alternative energy systems. As part of the installation process, the cost savings provided by the distributed energy source will also be identified. These cost savings depend on the electrical rate structure at the installations. Based on the installation's rate structure, the alternative energy facility may provide savings by reducing peak electrical demand, utilizing time of use pricing, and leveraging other incentives offered by the utility.

## **Vehicle Purchase and Lease Periods**

Most of the Army's vehicles are leased. As stated before, typical lease periods for light duty vehicles are three to four years for automobiles and seven years for light trucks. It may be appropriate to examine the lease periods in order to help manage overall implementation costs and increase incremental cost payback opportunity. As a part of Phase II/Step 1 – the purchase and/or lease period of advanced vehicles will be analyzed to determine an optimal approach.

## **Data Collection, Dissemination and Business Case**

The goal of Phase II/Step 1 is to validate a path for the nation to achieve energy security. This path includes goals of eliminating dependence on foreign supplied petroleum, a 60% reduction of greenhouse-gas generation and securing the national grid. A key objective of the AVPI is to encourage national adoption. Validation of the business case is a key element of influencing early and late adopters to make the move to advanced vehicles connected to the grid. To generate the business case, Phase II/Step 1 data collection requirements include baseline and AVPI implemented:

- Energy consumed and costs for same (fuel and electric energy)
- Calculated gallons of gasoline equivalent and miles per gallon
- Renewable energy generated

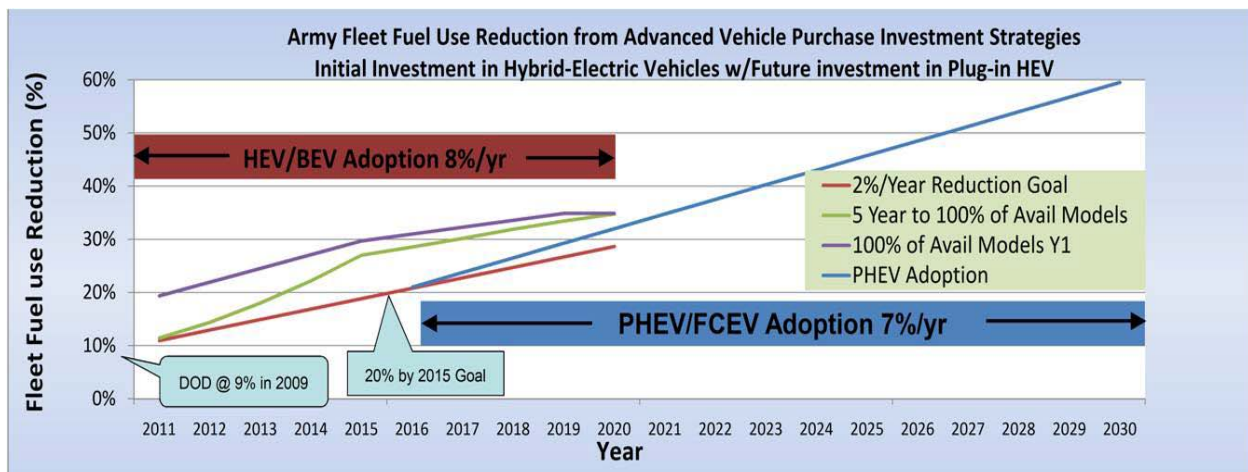


- Vehicle miles driven by vehicle category
- Implementation costs – Infrastructure modifications required for integration of renewable energy systems, vehicle charging systems, and grid management systems
- Capital costs for vehicle and renewable infrastructure mix by geographic area
- Maintenance costs and intervals associated with vehicle, renewable infrastructure, and inspection of installations
- Vehicle duty cycles capturing operational time, lingering and use patterns

**Phase II/Step 1 will develop a menu of approaches for meeting the goal of a net 60% reduction in petroleum consumption and GHG generation, and securing the electrical grid.** The methods, data, and results of the pilot integration will be broadcast to the balance of the DOD, US and State Governments, communities, industry, and the public to help the nation plan its way forward. Information collection will be coordinated with and disseminated to local utilities to assure that program data directly benefits local utility infrastructure planning. Successful pilot integration is one of two keys to initiating Step 2 of Phase II.

### ***Phase II – Step 2 – PHEV and FCEV Non-tactical Fleet Procurement***

Non-tactical fleet conversion to PHEVs and FCEVs is dependent upon successful completion of the pilot integration of Phase II/Step 1 and the commercial availability of vehicles. This procurement plan is shown notionally in Figure 8. A replacement rate of 7% of the Army's NTV fleet per year (approximately 5800 vehicles per year) accelerates the petroleum reduction rate providing for the opportunity to achieve a 60% reduction by 2030. Vehicle procurement and conversion from HEV and BEV purchases should start as the PHEV and FCEV vehicles become commercially available. It is assumed that large-scale adoption will start between 2016 and 2020. It is also assumed that PHEV and FCEV purchases will be supported by renewable power generation to charge the energy storage systems. A total planned incremental funding of \$150 million per year for 15 years is suggested to achieve fleet replacement and the initiative's goals.



**Figure 8 - Advanced Vehicle Implementation vs. effect on Petroleum consumption**

Table 6 below shows the breakdown of the Army's non-tactical fleet with a 7% per year replacement rate applied evenly for Phase 2 totaling roughly 5800 replacements per year. An AVPI-like Government-wide initiative for Phase II would involve 47,000 vehicle replacements per year at an incremental replacement cost of \$1.2B per year.

Army Non-Tactical Vehicle Fleet	Light Duty Vehicles					Medium Duty Vehicles					Heavy Duty Vehicles	Total Vehicles
	Sedans & Station Wagons	Vans	SUVs	Light Trucks		Buses	Amb	Vans	SUVs	Trucks		
				4x2	4x4							
OWNED	386	551	1,106	961	2,545	119	58	240	380	2,357	2,238	10,941
GSA Lease Fleet	19,393	12,093	5,386	5,570	4,376	2,195	265	7,536	430	9,530	3,574	70,348
Non-GSA Lease	100	336	36	153	244	262	6	249	72	38	75	1,571
Total Fleet	19,879	12,980	6,528	6,684	7,165	2,576	329	8,025	882	11,925	5,887	82,860
Phase 2 - Yearly Replacement	1392	909	457	468	502	180	23	562	62	835	412	5800

**Table 6 - Phase II/Step 2 Yearly Vehicle Replacement volumes at 7% per year**

## Kit Conversion of Vehicles

Conversion of existing HEV vehicles to PHEV may be more cost effective than new vehicle purchases. For instance, trucks and buses are long life vehicles. Conversion of trucks and buses from HEV to PHEV may be more practical. Unlike an automobile, truck integration and packaging of hybrid systems is not as rigorous and space constrained. Replacement of the HEV battery with a higher energy PHEV battery, along with a replaced or re-flashed hybrid control unit and charging system may be a very cost effective approach. There are other possible kit-level conversions that will be considered as a part of the Phase II implementation.

## AVPI Estimated Cost

The estimated incremental cost for the three Phases is shown below in Table 7 :

Investment Strategy	Average Investment/ Year, \$M/yr	Investment Duration, Years	Investment, \$M
Phase I - HEV and BEV Procurement	\$125	10	\$1,250
Phase II/Step 1 - PHEV & FCEV Pilot Integration	\$24	3	\$72
Phase II/Step 2 –			
PHEV & FCEV Procurement	\$150	15	\$2,250
Renewable Energy Systems	\$67	15	\$1,000
Total Investment			\$4,572

**Table 7 - Estimated Investment Cost for the AVPI**

In total – The planned duration of the effort is 20 years. Phase II spans all 20 years – Phase II Step 1 is a 5 year effort that includes:

- one year of planning, modeling and simulation
- 3 years of capital investment, implementation, data gathering and modeling refinement
- 1 additional year of data gathering and continued modeling refinement with focus on flexible parametric utility to validate a tool ready for re-use at other installations and communities.

Phase II Step 2 is a 15 years acquisition execution plan with the right mix of advanced vehicles and renewable charging infrastructure based on the validated modeling and simulation tool developed from Step 1.

### ***Implementation Strategy***

Potential funding partners for the AVPI are the DOD, DOE (such as Clean Cities and CMAQ funding), and State and local governments.

Program oversight of the total effort will be provided by US ASA I&E and ASA ALT.

Vehicle procurement will be managed by US Army ACSIM. GSA will support with vehicle availability as able, available, and capable. Commercial vehicle manufacturers will supply their latest state-of-the-art technologies which enable successful execution of the AVPI.

Installation investments to support the BEV, PHEV, FCEV, renewable energy power systems, and facilities will be managed by IMCOM and supported by US Army Corps of Engineers- Engineer Research and Development Center - Construction Engineering Research Laboratory(ERDC-CERL), TARDEC, and Industry Suppliers.

Facility development to support the export power to the installation and “Net Zero Energy” grid and smart grid modeling, simulation, and development will be managed by IMCOM, CERL, National Renewable Energy Laboratory (NREL), interested Utility partners, Suppliers, and Academia.

## **Key Stakeholders and Roles**

### ***Government***

Army Fleet Managers – Army fleet managers will be responsible for identifying the appropriate legacy vehicles for replacement with advanced vehicles. They will be instrumental in providing guidance on appropriate protocols for ensuring data collection. They will lead in advanced vehicle and vehicle related procurement to meet the 2%/year petroleum reduction mandate.

DOD R&D Community – The DOD R&D community will assess future and advanced technologies for use in the initiative. They will also gather and monitor both platform and subsystem performance and reliability information and provide feedback to industry stakeholders. They will be responsible for proactively identifying opportunities for inserting current R&D into the advanced vehicle fleet.

DA IMCOM – IMCOM will be responsible for coordinating and managing all infrastructure related issues for both the integration of the advanced vehicle fleet onto the installations as well as the construction and implementation of renewable resource generation. They will lead in formulating the right mix of renewable generation technologies for facilities based on available resources and facility needs.

Department of Energy – As the federal lead for national smart grid development and implementation, DOE will offer salient guidance on system interfaces to the national grid. DOE expertise on installation energy analysis, modeling, and technology integration will be a critical project resource.

GSA –GSA will advise on cost negotiations as well as support for the advanced vehicle acquisition. GSA will identify advanced vehicles already on the production and acquisition schedule and help determine the most efficient phased acquisition schedule for the initiative.

Army Corps of Engineers – The Army Corps of Engineers (ACE) will act in a role of close coordination with IMCOM to support the construction and infrastructure portions of this initiative as well as conduct modeling efforts to determine the right mix of vehicle and renewable technologies.

## ***Industry***

Automotive and MD/HD OEMs – The OEMs would be responsible for building and delivering the advanced vehicles, consulting on infrastructure requirements and vehicle-to-grid issues, including communications. They would also coordinate closely with GSA for planning the future year vehicle availability to accommodate the phased deployment schedule.

Automotive and MD/HD suppliers and technology developers – Key industry suppliers and technology developers would share knowledge gained through the deployments, make suggestions on new capabilities for consideration in future year deployments and speed the improvement of system and sub-system development. These partners will contribute to vehicle and component level data analysis.

Vehicle Infrastructure Providers – These companies provide critical technologies including both hardware and software products to enable vehicle charging, grid connectivity and fleet management. Particular attention will be paid to information security at the different interfaces with the increased level of vehicle connectivity.

Utility providers – Utility providers will be responsible for consulting and implementing energy system control and metering. They will also work closely with IMCOM and the vehicle OEMs to coordinate certain aspects of V2G communications.

Energy companies – The energy companies will be responsible for the design, installation, management, and maintenance of renewable energy generation systems. They will work closely with IMCOM, ACE, and the utility providers for construction and infrastructure requirements. They may also serve as important agents that may leverage federal funds by exercising tax credits.

Power Distribution System Providers – These companies will define upgrades to the overall multi-facility power distribution infrastructure that are supported by modeling and simulation.

These upgrades, when implemented, will improve energy and power management across the infrastructure through the addition of reconfigurable energy storage, peak demand reduction, sub-segment or total infrastructure islanding in a manner that also meets the energy security/surety requirements.

## ***Small Business***

Small business is an important factor in the strength and recovery of the U.S. economy. According to the U.S. Small Business Administration, small businesses:

- Represent 99.7% of all businesses
- Employ half of all private sector employees
- Pay 45% of total U.S. private payroll
- Generated 60-80% of net new jobs annually over the last decade, and
- Employ 41% of high tech workers (i.e. scientists, engineers, and computer workers).
- Small, high-tech, innovative companies have the opportunity to work with the federal government in research and development efforts through the Small Business Innovation Research (SBIR) Program.

TARDEC collaborates with small business through the Small Business Innovation Research (SBIR) program to make significant advancements in vehicle power generation, energy storage, and power management & control technologies. TARDEC continues to work through the SBIR program to develop and demonstrate safe and robust vehicle-grid solutions for military vehicles. The AVPI is committed to leveraging promising technologies from small business.

## **Desired Outcomes**

The desired outcome of the AVPI is to accelerate Army adoption of advanced vehicles that reduce petroleum consumption and emissions, and are capable of importing and exporting grid electric power and/or islanding power for installations. The ultimate goal of the AVPI is to validate a path to energy independence for the US - a 60% reduction in fossil fuel consumption and GHG generation reduction – and bolster installation power generation to assure power availability to military installations in uncertain times. Along the way to achieving the goal, the mandated reductions of petroleum use, use of low GHG emitting vehicles, and utilization of alternative fuels will be met.

The expected return on investment of this initiative is to establish the Army as a leader in petroleum and emissions reduction and to establish a path toward national energy security by:

- Focusing on a **60% net reduction in petroleum use and GHG generation** vs. a 2005 baseline of the Army's non-tactical vehicle fleet

- Achieving a minimum of **2%/year reduction in the Army's petroleum use and GHG emissions** through 2030
- **Securing Army installations' electrical grid power supply**
- Taking a lead role for the nation in V2G electrical system integration and standards development and implementation
- Providing a roadmap for the nation to eliminate dependence on foreign-supplied oil and secure the nation's electrical grid
- Accelerate adoption of advanced vehicle and sustainable energy oriented high technology jobs
- Stimulating the production of advanced plug-in vehicles to help drive down production and product costs to facilitate broader consumer adoption
- Providing renewable energy supply for installations of roughly 1 million megawatt-hours/year for vehicle charging and installation use (>10% of installations total energy yearly demands)
- Establishing installation grid connection between vehicles and renewable sources

## **Addendum - Policy and Legislation**

### ***Federal Leadership in Environmental, Energy and Economic Performance***

On October 5<sup>th</sup>, 2009 a new Executive Order 13514 was released that sets the Federal Government on the course “to establish an integrated strategy towards sustainability” and to make reduction of GHG emissions a priority for Federal agencies. This Initiative supports the Order’s goals of increasing the use of renewable energy and reducing the use of fossil fuels.

### ***The Energy Independence and Security Act of 2007 (EISA)***

EISA prohibits agencies from acquiring any light-duty motor vehicle or medium-duty passenger vehicle that is not a “low GHG emitting vehicle.” EISA also established the requirement of decreasing annual vehicle petroleum consumption at least 20% from a FY2005 baseline. EISA revises the Corporate Average Fuel Economy (CAFE) standards for motor vehicles increasing the fuel economy requirement to 35 mpg by 2020. EISA includes measures to increase efficiency and promote low-carbon technologies in areas of electricity generation and electricity use.

### ***The Energy Policy Act of 1992 and 2005 (EPACT)***

EPACT 92 gave an initial mandate for the use of alternative fuel vehicles in federal fleets. This was followed up by EPACT 05 which launched multiple federal programs investigating and demonstrating advanced vehicle technologies including plug-in hybrid and hydrogen fuel cell vehicles.

### ***Army Energy Security Implementation Strategy***

The Army Energy Security Mission is to “make energy a consideration for all Army activities to reduce demand, increase efficiency, seek alternative sources, and create a culture of energy accountability while sustaining or enhancing operational capabilities.” To accomplish this mission, the Army developed five strategic energy security goals (ESG) with multiple objectives aligned to each goal.

**ESG 1.** Reduced energy consumption

**ESG 2.** Increased energy efficiency across platforms and facilities

**ESG 3.** Increased use of renewable/alternative energy

**ESG 4.** Assured access to sufficient energy supplies

**ESG 5.** Reduced adverse impacts on the environment

The AVPI directly affects the following objectives:

**Objective 3.2.** Achieve the optimum mix of the most current vehicle technologies to reduce fossil fuel consumption and GHG emissions within the Army NTV fleet.

**Objective 4.2.** Develop on-site renewable generation program (consistent with mission requirements) to create “Net Zero Energy” installations.

The AVPI also supports the following objectives:

**Objective 1.7.** Establish an automated fuel accountability system to validate baseline fuel consumption and provide consistency and accuracy to enterprise level fuel asset visibility.

**Objective 2.3.** Improve fuel efficiency of the Army NTV fleet that uses conventional fuels.

**Objective 3.1.** Substitute renewable resources for purchase of energy and fuel from fossil fuel sources where life cycle costs are effective.

***Objective 5.1. Reduce GHG emissions by reducing the use of fossil fuel.***  
***American Recovery and Reinvestment Act (ARRA) of 2009***

On February 17, 2009 Government passed the ARRA also referred to as the Stimulus or The Recovery Act. The ARRA is an economic stimulus package enacted by the 111<sup>th</sup> United States Congress. The ARRA is an act making supplemental appropriations for job preservation and creation, **infrastructure investment, energy efficiency and science**, assistance to the unemployed, and State and local fiscal stabilization, for the fiscal year ending September 30, 2009, and for other purposes.



## **GLOSSARY**

ACSIM - Assistant Chief of Staff for Installation Management  
ARRA - American Recovery and Reinvestment Act  
ASA I&E – Assistant Secretary of the Army for Installations and Environment  
ASA ALT – Assistant Secretary of the Army for Acquisition, Logistics and Technology  
AVPI – Advanced Vehicle and Power Initiative  
BEV – Battery Electric Vehicle  
CO<sub>2</sub> – Carbon Dioxide  
CERL - Construction Engineering Research Laboratory  
CFL – Compact Florescent Light  
CMAQ – Congestion Mitigation and Air Quality  
CONUS – Continental United States  
DA – Department of the Army  
DOD – Department of Defense  
DOE – Department of Energy  
EIA – Energy Information Administration  
EISA – Energy Independence and Security Act  
EPA – Environmental Protection Agency  
EPACT – Energy Policy Act  
ERDC CERL – Engineer Research and Development Center – Construction Engineering Research Laboratory  
ESG – Energy Security Goals  
EVSE – Electric Vehicle Support Equipment  
FCEV – Fuel Cell Electric Vehicle  
FOB – Forward Operating Base  
G2V – Grid to Vehicle  
GAO – Government Accountability Office  
GHG – Green-House-Gas  
GSA – General Services Administration  
HEV – Hybrid Electric Vehicle  
HHV – Hybrid Hydraulic Vehicle  
ICE – Internal Combustion Engine  
IEEE – Institute of Electrical and Electronics Engineers  
IMCOM – Installation Management Command  
ISO – International Standards Organization  
LED – Light Emitting Diode  
MD/HD – Medium Duty and Heavy Duty  
MRAP – Mine Resistant Ambush Protected  
MW – Mega Watts  
MWh – Mega Watt Hours  
NIST – National Institute of Standards and Technology  
NREL – National Renewable Energy Laboratory  
NTV – Non-Tactical Vehicle  
OCONUS – Outside the Continental United States  
OEM – Original Equipment Manufacturer  
OPEC - Organization of the Petroleum Exporting Countries  
PHEV – Plug-in Hybrid Electric Vehicle  
SAE – Society of American Engineers

SBIR – Small Business Innovation Research

TARDEC – Tank Automotive Research, Development and Engineering Center

V2G – Vehicle to Grid

## Contacted and Contributing Organizations

A123 Systems	FEDEX	RCT Systems, Inc.
AeroVironment Inc.	Fisher Coachworks	Ricardo
Aker Wade Power Technologies LLC.	Florida Power and Light	Saft Batteries
Alipro	Ford	SAIC
Allison	Freightliner	Sandia National Laboratory
ALTe LLC	GE Global Research	Satcon
AM General, LLC	Global ET	SES Inc. USA
Argonne National Laboratory	General Motors	Smith Electric Vehicles
Arvin Meritor	GTR Development LLC	Southern California Edison
	Hawaii Center for Advanced	
Automotive Insight	Transportation Technology	SWRI
Automation Alley	Honeywell	U.S. Fuel Cell Council
Automotive Insight	Hydrogenics Corporation	University of Hawaii at Minoa
AVL Powertrain Engineering, Inc.	IAV Automotive Engineering Inc	University of Michigan
Azure Dynamics	Idaho National Laboratory	UPS
BAE Systems	IPERC	US Air Force I&E
Ballard	ISE Corporation	US Army - ASA I&E
Battelle	Jankel Group	US Army - CERDEC
Bosch Rexroth	JCI Saft	US Army - CERL
Bright Automotive	Kokam America	US Army ACS IMISD
BRTRC	L-3	US Army ACSIM
Burtek Inc.	Lockheed Martin	US Army AMC
California Fuel Cell Partnership	Mack Trucks	US Army ASA (I&E)
		US Army Garrison-Detroit Arsenal
CALSTART	Magna Steyr	DPW
	Michigan Economic Development	
Caterpillar	Corporation	US Army HQ IMCOM
Chrysler Group LLC	Michigan State University	US Army HQDA
	Missouri University of Science and	
Colorado State University	Technology	US Army TARDEC
DDR&E, Laboratories	MIT	US Army TRADOC
Delphi Corporation	Nabmag Technologies	US CAR
	National Energy Technology	
Dow Automotive Systems	Laboratory	US DOD Power Surety TF
DRS Technologies	National Hydrogen Association	US Dept. Of Energy
DTE Energy	Navistar	US DOE FEMP
Duke Energy	NEXTEK Power Systems	US FEMP/Army
Eaton	NextEnergy	US GSA
	National Renewable Energy	
EBO Group	Laboratory	US Marine Corps Energy Ofc.
Eetrex Incorporated	Oak Ridge National Laboratory	US Navy
Electric Power Research Institute	Oshkosh Truck	US OSD
Electricore, Inc.	PACCAR	UTC Power Corporation
	Pacific Northwest National	
ENERDEL	Laboratory	Venture Management Services
		Wayne County - Dept of Economic
ENOVA	PG&E	Development
		White House Office of Science
Electric Power Research Institute	Quantum Technologies	&Technology Policy